ORIENTAL JOURNAL OF CHEMISTRY
An International Open Access, Peer Reviewed Research Journal

www.orientjchem.org

ISSN: 0970-020 X
CODEN: OJCHEG
2025, Vol. 41, No.(1):
Pg. 152-157

Synthesis of Dye Sensitized Solar cell using Rhodamine B Dye and Study of their Applications in Conversion Efficiency of Solar cell into Electrical energy

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http://dx.doi.org/10.13005/ojc/410118

(Received: September 10, 2024; Accepted: January 28, 2025)

ABSTRACT

A solar cell that is sensitive to dyes was created by combining Rhodamine B Dye with TiO_2 as a nonmaterial. With t1/2 as the performance metric, it was determined that the dark-operating time of the Rhodamine B, EDTA, and TiO_2 cell was 210.0 minutes. A number of factors were studied, including the following: pH, light intensity, reluctant concentration, dye concentration, time-dependent potential fluctuation, time-dependent photocurrent, and the influence of TiO_2 dosage concentration. Additional research focused on the cell's I-V (current-voltage) characteristic. An efficiency of 0.781 and a fill factor of 0.289 were both within the realm of possibility.

Keywords: Rhodamine B dye, Photocurrent, Current-voltage and Solar cell.

INTRODUCTION

A major concern to humanity today is the fast depletion of energy supplies caused by the rising consumption of fossil fuels. Renewable energy sources are growing in popularity, and solar power is among the most promising. Because it is a practical medium for converting solar energy, photochemical energy conversion is of interest to researchers. Photo galvanic solar cells are photo electrochemical devices that can generate and store solar energy all at once. Radial and Williams[1] observed the photo galvanic phenomenon for the first time in 1925 and Rabin witch continued to study it, and this phenomenon is the basis of photo galvanic cells.

The concept of using the photo-galvanic effect to convert and store solar energy was born out of researchers' meticulous examination of the phenomena. Countless published investigations on photo galvanic cell systems provide credence to this notion. In photo galvanic cells, which are great examples of photoelecrochemical devices, it is normal practice to submerge the anode and cathode in an alkali medium containing a photosensitizer and reluctant.

Many substances, such as Bib Rich Red, Azure-B, Azure-A, Rose Bengal, Eosin, Brilliant Cresol Blue, Rhodamine-B, and many more, can be utilized as photo-sensitizers. As more instances, there are methyl violet[2], ethylene blue[3,4], and others.

Optimal electrical cell performance is affected by variables such light sensitizer concentration, reluctant concentration, and solution pH, according to a research review. These characteristics must be state-of-the-art for photo-galvanic cells to work more efficiently.

Additionally, the literature research shows that EDTA is a very safe, stable organic acid with a significant capacity for colour reduction. In light of these facts, the Rohdamine-EDTA combination has been utilised to enhance photo galvanic cell performance.

MATERIAL AND METHOD

Materials

The following chemicals was used in the synthesis and performance of dye sensitized solar cell:

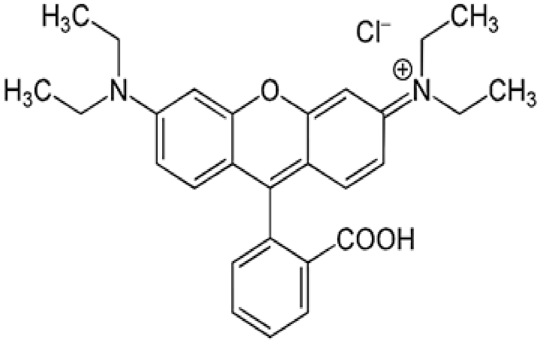
Table 1:

Sr. No	Chemicals	Specifications
1	Rhoda mine B	Loba Chemie, Mumbai
2	EDTA	Ases Chemical, Jodhpur
3	TiO_2	Sisco Research Laboratories, Mumbai
4	Oxalic Acid	Ranbaxy, Mumbai
5	Sodium hydroxide	RFCL, New Delhi
6	Phenolphthalein	Sisco Chem, Mumbai

Properties of Dyes (Photosensitizes) Rhodamine B

Chemical formula: $C_{28}H_{31}ClN_2O_3$
IUPAC Name: 9-(2-Carboxyphenyl)-6-(diethylamino)-N,N-diethyl-3H-xanthen-3-iminium-chloride
Molecular mass: 479.02 g mol^{-1}
λ_{max}: 554 nm

Structural formula



Preparation of Solutions

All solutions, including dye solutions, M/100 EDTA, 1M NaOH, and 0.5M oxalic acid, were made with double-distilled water. Direct weighing was used to make synthetic dye stock solutions (M/100), which were then stored in colored containers to keep light out.

Experimental Set-Up of the Photo Galvanic Cell

An H-type glass tube was filled with a mixture of dye, surfactant, reluctant, and NaOH solutions, and it was blackened with black charcoal paper to shield it from sunlight. A saturated calomel electrode was situated at one end of the H-tube, while a lustrous Pt foil electrode (1.0 x 1.0 cm^2) was situated at the other. The SCE functions as a counter electrode, while the platinum electrode serves as the active electrode. The system was initially maintained in a state of darkness until a stable potential was achieved. Subsequently, a Philips 200 W tungsten lamp was employed to illuminate the limb that contained the platinum electrode. The thermal radiation was eliminated by employing a water filter. The photochemical bleaching of the dye was examined using the potentiometric technique.

The current generated by the system was measured using a Nucon micrometer, and the potential was detected using a Systronics 335 digital pH meter. The current voltage characteristics were examined via incorporating an external load into the circuit of the photo galvanic cell configuration and a carbon pot.

RESULT AND DISCUSSIONS

Potential Changes Over Time

1 milliliter of M/1000 Dye (Rhodamine B), 5 milliliters of M/100 EDTA, 5 milliliters of TiO_2, and 14 milliliters of doubly distilled water made up the 25 milliliter solution. In this experiment, a photogalvanic cell was used to investigate the fluctuation of the photo potential over time. After the photogalvanic cell's potential stabilized, the platinum electrode was placed in the same light source. After reaching a maximum value (Vmax) due to illumination, the potential remained relatively steady. After the light source was removed, the potential changed in the opposite direction and, after a while, a stable potential was once more obtained.

Table 2 provides the potential variation in the Rhodamine B-TiO_2-EDTA System with regard to time, and Fig. 1 shows this variation graphically.

Table 2: Variation of Potential with Time for Rhodamine B–TiO_2 -EDTA system

Time (min)	Photopotential (mV)
0	1007 dark potential
15	1086
30	1103
45	1107
60	1108
75	1111
90	1115
105	1123
120	1125
135	1127
150	1130
165	1137
180	1145
195	1154
210	1163
225	1170
240	1177
255	1184
270	1190
285	1192
300	1220 (max)
315	1180
330	1170
345	1168
360	1152
375	1150
390	1149
405	1146
420	1130
435	1120

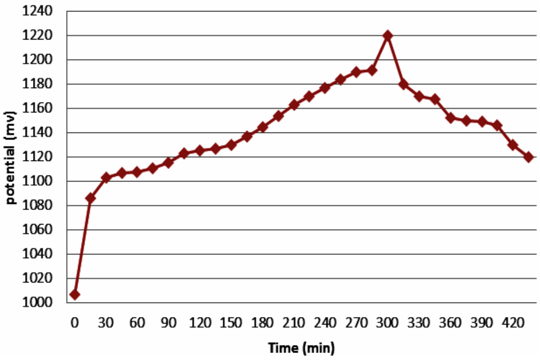


Fig. 1. Variation of Potential with Time

Time Dependent Shifts in Photocurrent:

The Rhodamine B-TiO_2-EDTA System's photocurrent increased rapidly upon illumination and reached its maximum value in a matter of minutes. Imax stands for "Maximum Photocurrent," which is the value in question. At equilibrium, it was found that the current declined with increasing light intensity and then approached a constant amount.

This value is denoted by the letters ieq (Photocurrent at equilibrium). It was discovered that eliminating the source of light led to a reduction in the amount of photocurrent. The report on the change in photocurrent that occurs in the Rhodamine B–TiO_2-EDTA System throughout the course of time can be found in Table 3, and Fig. 2 displays the data in graphical form.

Table 3: Variation of Photocurrent with Time for Rhodamine B–TiO_2-EDTA system

Time (min)	Photocurrent (μA)
0	43
15	54
30	56
45	59
60	63
75	65
90	67
105	71
120	74
135	79
150	80
165	88
180	97
195	98
210	102
225	107
240	109
255	112
270	118
285	121
300	138 (max)
315	136
330	135
345	134
360	133
375	132
390	131
405	130
420	130
435	129

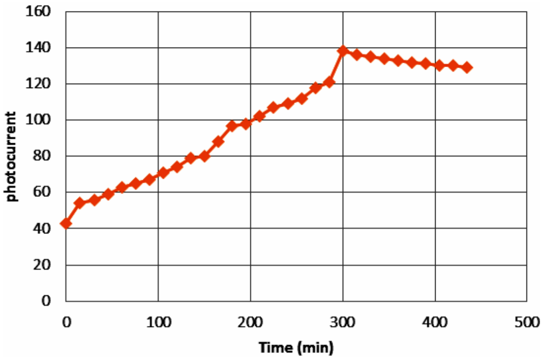


Fig. 2. Variation of Photocurrent with Time

The Effect of Change in Concentration of Rhodamine B

When we looked at how different dye concentrations affected cell performance, everything else was the same. The results showed that when the concentration of the dye (Rhodamine B) increased, so did the photopotential and photocurrent. Once the cell's electrical output reached a certain concentration of Rhodamine B, it began to decrease. This was determined to be the point at which the maximum was reached. 1 milliliter of M/1000 Dye (Rhodamine B), 5 milliliters of M/100 EDTA, 5 milliliters of TiO_2, and 14 milliliters of doubly distilled water made up the 25 milliliter solution. In this experiment, a photogalvanic cell was used to investigate the fluctuation of the photo potential over time.

Table 4: Power, Photocurrent, and Photopotential as a Function of Dye Concentration

Rhodamine B–TiO_2 -EDTA System	RHODAMINE-B				
	1.0	2.0	3.0	4.0	5.0
Photopotential (mV)	1220	1267	1299	1108	1100
Photocurrent (μA)	138	186	198	144	131
Power (μW)	118.23	231.64	315.18	231.80	126.94

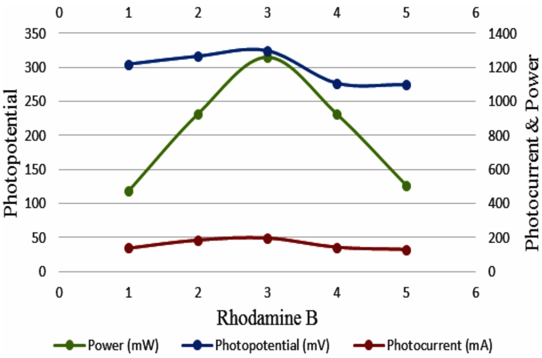


Fig. 3. Power, Photocurrent, and Photopotential Variability as a Function of Dye Concentration

The impact of Changes of EDTA Concentration

With the exception of EDTA concentration, all other variables were controlled to determine the effect of concentration variability on the cell's electrical output. It was shown that as the EDTA concentration increases, the photopotential increases as well, eventually reaching its maximum value. It was observed that as the EDTA concentration was increased, the cell's electrical generation decreased. Table 5 and Fig. 4 detail the effects of different EDTA concentrations on the photopotential and photocurrent of the Rhodamine B-TiO_2-EDTA systems, while Fig. 4 provides visual representations of these effects. The experimental data is presented in the following table.

Table 5: Variability of Photopotential, Photocurrent and Power by EDTA Concentration

Rhodamine B–TiO_2-EDTA System	1.0	2.0	[EDTA] 3.0	4.0	5.0
Photopotential (mV)	1223	1230	1245	1234	1220
Photocurrent (μA)	115	178	246	150	138
Power (μW)	116.31	231.18	348.87	252.12	118.23

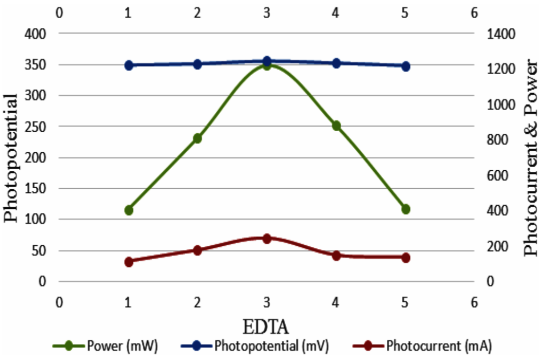


Fig. 4. How Concentration of EDTA Affects Photopotential, Photocurrent, and Power

The Impact of [TiO_2] Dose Variation

The Rhodamine B-TiO_2-EDTA System was used to study effect of change in [TiO_2] concentration on photoelectric characteristics of the cell while keeping all other components constant. When [TiO_2] concentration was increased to a maximum amount, it was noticed that the cell's electrical output increased as well. Photopotential, photocurrent, and photogalvanic cell power all decreased as their concentrations increased more. Fig. 5 provides a pictorial representation of the results, which are given in Table 6.

Table 6: The Effect of TiO_2 Concentration on Photopotential, Photocurrent, and Power

Rhodamine B–TiO_2-EDTA System	1.0	2.0	TiO_2 3.0	4.0	5.0
Photopotential (mV)	1124	1029	1188	1122	1100
Photocurrent (μA)	128	162	198	160	131
Power (μW)	122.91	259.13	363.94	252.34	118.23

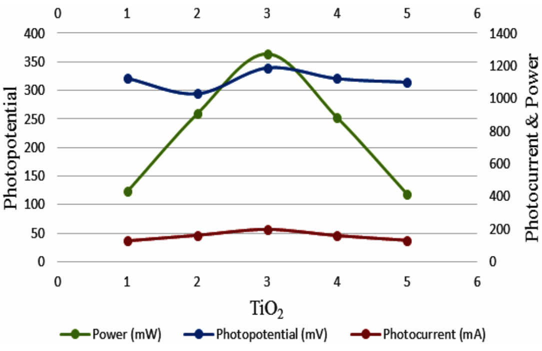


Fig. 5. Tio_2 concentration-related variability in photopotential, photocurrent, and power

Current-Voltage (i-V) Characteristics of Cell

Measurement of short circuit current (i_{sc}) and open circuit voltage (V_{oc}) of the photogalvanic cell were done using an Osawa micrometer to close the circuit and a KROSS-S DT 830D multimeter with digital display to open it. The digital multimeter's circuit was attached to an outside load, such as a carbon pot, and both the current and potential values between these two ultimate values were recorded. Table 7 provides an explanation of the current-voltage (i-V) characteristics of the system, which are graphically depicted in Figure 6.

Table 7:

Sr. No	Photocurrent (μA)	Potential (mV)	Power (μW)
1	230	40	27.59
2	220	90	41.33
3	210	140	53.51
4	200	200	64.36
5	190	260	74.82
6	180	330	87.22
7	170	390	92.86
8	160	450	99.29
9	150	520	106.45
10	140	580	118.23
11	130	640	105.25
12	120	710	99.38
13	110	780	91.65
14	100	850	83.12
15	90	910	75.28
16	80	970	66.73
17	70	1025	57.86
18	60	1050	48.26
19	50	1075	41.27
20	40	1100	33.15
21	30	1120	26.80
22	20	1155	23.25
23	10	1190	17.20
24	00	1220	00.00

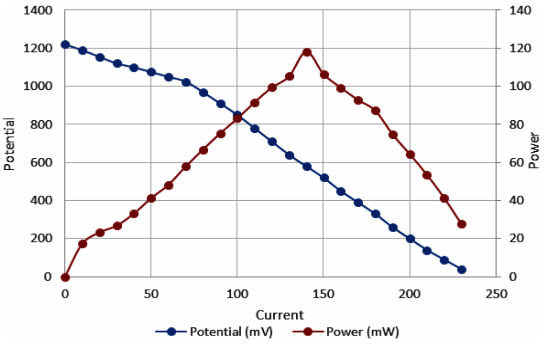


Fig. 6. I-V Cell Characteristic, (b) Power vs. Current, and (c) Potential and Power Variability with Current

The i-V curve, which represents the current, was found to have lost its distinctive rectangular shape. The fill-factor was determined to be 0.289 using the following formula, and the maximum value of the product of photocurrent and photopotential was determined to be 0.289 at Power Point (pp), a point on the i-V curve.

$$\text{Fill factor}(\eta) = \frac{V_{pp} \times i_{pp}}{V_{oc} \times i_{sc}}$$

$$= \frac{140\ X\ 580}{230\ X\ 1220}$$

$$= 0.289$$

V_{pp} is the photopotential intensity and i_{pp} is the photocurrent intensity at power point. The voltage across an open-circuit is represented by V_{oc}, while the current across a short circuit is represented by i_{sc}.

Cell Performance

Once the potential became stable, the light was turned off and an external load was introduced to test the photogalvanic cell's performance. The potential required to have stabilized before this could be done. Time to half-life was used to evaluate the performance. For a total of 210.0 min, the cell containing Rhodamine B, EDTA, and TiO_2 could be operated in darkness. The findings are summarized in Table 8, and the time-power curve provides a graphical representation of the data (Figure 7).

Table 8: Study of the Half-life of the Cell

Time (Minutes)	Power (W)
0	118.23(max.P_{pp})
50	104.15
70	97.19
90	91.26
110	86.12
130	80.22
150	73.62
170	69.23
190	63.26
210	58.20($t_{1/2}$)
230	52.71
250	49.13
270	44.76
290	40.23
310	36.16
330	32.17
350	26.49

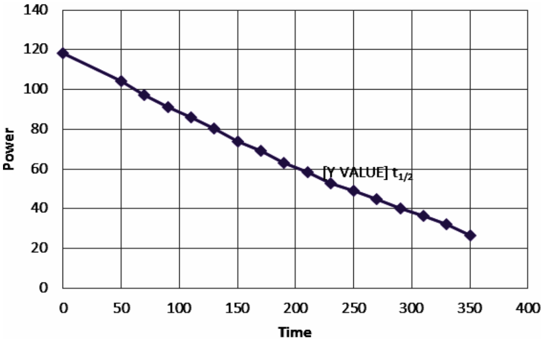


Fig. 7. Time-Power Curve of the Cell

Cell Conversion Efficiency

By entering the radiation's incident power, current, and potential values at the power point and solving for the resulting voltage, one can ascertain a cell's conversion efficiency.

$$\text{Conversion efficiency} = \frac{V_{pp} \times i_{pp}}{A \times 10.4 mWcm^{-2}} \times 100\%$$

Where, A represents the electrode area of platinum foil electrode (1 cm^2)

$$= \frac{140\,X\,580}{1\,X\,10.4\,X\,10^6} X\ 100 = 0.781$$

CONCLUSION

When EDTA and Rohdamine B dye were utilized in the current study, the conversion efficiency and fill factor were determined to be 0.781 and 0.289, respectively. In this work, I also observed that the pH of the solution decreases with cell illumination and eventually becomes constant. For the good improvement of DSSC in the future, a mixture of photosesitizers with broad absorption at UV-Visible regions may be used.

ACKNOWLEDGMENT

I would like to express thanks to my research guide Dr. R. C. Meena, Professor, Department of Chemistry, Jai Narain Vyas University, Jodhpur, For his excellent guidance, encouragement, motivation and suggestions.

Conflict of interest

The authors declare no conflict of interest in the present work.

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